PATENT SPECIFICATION

DRAWINGS ATTACHED

831,692

Date of filing Complete Specification: Nov. 15, 1957.

Application Date: Nov. 15, 1956. *No. 35002/56.*

Complete Specification Published: March 30, 1960.

Index at acceptance:—Class 37, A19(F: H: L3).

International Classification:—G08c.

COMPLETE SPECIFICATION

Improvements in or relating to the Measurement of the Electrical Conductance of Liquids

We, THE WAYNE KERR LABORATORIES LIMITED, a British Company, and RAYMOND CALVERT, a British Subject, both of the Company's address, 3, Sycamore Grove, New Malden, Surrey, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to the measurement of the electrical conductance of liquids.

The normal methods for measuring the conductance of a liquid require that electrodes should be arranged in contact with the liquid in order to make electrical connection between the liquid and the measuring circuit. Difficulties arise in the use of electrodes from chemical action of the liquid on the electrodes and/or from generation of gases which are absorbed on the surface of the electrodes. There are thus considerable difficulties in measuring, for example, the conductance of a very corrosive liquid.

It has been proposed in Specification No. 695,058 to measure the conductance of a liquid by arranging an insulating tube containing the liquid in the form of a closed loop linked with two transformer cores, one of which carries a primary winding energised with alternating current and the other of which carries a secondary winding connected to a current measuring instrument. The coupling between the two cores depends on the conductance of the liquid and hence the meter reading is a measure of the conductance. In this apparatus it has also been proposed to provide a balancing circuit comprising windings on the two cores connected in series with one another and with an adjustable resistor which can be adjusted to balance out the conductance of the tube when the latter is empty.

It is an object of the present invention to provide an improved apparatus for measuring the conductance of a liquid making use of closed loop of liquid linking two transformer cores.

According to this invention, apparatus for measuring the conductance of a liquid comprises an input transformer with a core carrying an alternating current input winding and a secondary winding which latter forms a first ratio arm, said secondary winding being adjustably coupled by a standard conductance to an input winding on a second core having an output winding coupled to a null-balance detector in which a loop of liquid in an annular vessel is coupled around the core of said input transformer and around said second core, the loop being arranged to form thereby a second ratio arm as well as the conductance to be measured, whereby the coupling between the cores via the liquid loop may be balanced against the coupling via the standard conductance by adjustment of the latter coupling to give a null indication on the detector so that the adjustment of the coupling via the standard impedance is a measure of the conductance of the liquid loop. With this apparatus there are no electric connections between the liquid and the measuring circuit but the loop, or loops, of liquids forms the necessary coupling into the measuring circuit. It will be seen that, in contrast to the aforementioned arrangement of Specification No. 695,058, the apparatus of the present invention constitutes an alternating current transformer ratio arm bridge in which a null balance is obtained by an adjustment of the circuit, for example, adjustment of an adjustable standard conductance, and the required conductance measurement is determined from the values of circuit components and not dependent in any way on the magnitude of an output signal fed to a meter.

The standard conductance may be connected directly to the aforementioned secondary winding and either may be a variable standard or may be a fixed standard connected to an adjustable tap on the winding. Alternatively the standard conductance might be connected to a tap on a potentiometer, for example an

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alternating current decade potentiometer, connected across the secondary winding.

The liquid loop is preferably contained in an annular vessel of relatively non-conducting tubing, that is to say, the conductance of the tubing is small compared with the conductance of the liquid to be measured. As explained below, however, the conductance of the tubing can be measured and it is not therefore essential that the tube should be non-conductive. Conveniently glass or polythene tubing is employed.

In a simple form, the tubing might be a closed loop which is used in an upright plane with an inlet arranged at the top. The tubing would be filled completely with the liquid under measurement and the inlet closed, for example, by a stopper.

The form of bridge described above measures conductances in parallel and hence would measure the parallel conductance of the tubing and of the liquid. Thus, by making a first measurement using only the tubing without the liquid, the conductance of the tubing can be measured and hence a correction can be made to a measurement of the combined conduction of the tubing and liquid to correct for the conductance of the tubing. It will be appreciated however that errors will be minimised if the conductance of the tubing is made as small as possible. It will also be noted that the correction obtained by making a first measurement using only the tubing without the liquid will correct not only for the conductance of the tubing but also any cross-talk between the input and output circuits of the bridge.

In the simplest case the tubing makes only a single turn around each of the cores and generally this will be the most convenient form. The number of turns on the two cores determines the bridge ratio and if this is known and if the cross-sectional area and length of the tubing is measured, it is possible, by the bridge to determine the absolute value of the conductance of the liquid under test. If the cross sectional area of the tubing is not known with sufficient accuracy, the bridge could be calibrated by making a preliminary measurement with the tubing filled with a liquid of known conductivity.

Conveniently the detector winding is a primary winding of an output current transformer having a secondary winding which is connected to the detector.

The following is a description of one embodiment of the invention, reference being made to the accompanying drawings, in which:—

Figure 1 is a circuit diagram for explaining the embodiment, and

Figure 2 is a diagrammatic illustration of this embodiment.

Referring to Figure 1 of the drawings there is shown an alternating current bridge circuit having an input transformer 10 with a primary winding 11 to which is applied an alternating current input. The transformer 10 has a secondary winding 12 which is connected in a series circuit with an adjustable standard impedance 13 and a primary winding 14 of an output transformer 15. The output transformer 15 has a secondary winding 16 which is coupled to a detector 17. As will be described later with reference to Figure 2, the two transformers 10, 15 are coupled through the liquid as indicated by the dash line 18. The transformer windings are wound in such a sense that the current through the winding 14, which can be adjusted by adjustment of the impedance 13, balances the current induced in the winding 14 by the coupling through the liquid. When such balance is achieved, the detector 17 provides a null indication.

Referring to Figure 2, there is shown a tube 30 conveniently made of material having a high electrical resistance compared with that of the liquid to be measured. This tube is formed as a closed loop and is shown as being provided with an inlet 31 at its upper end and outlet 32 at its lower end, suitable valves indicated diagrammatically at 33, 34 being provided for controlling flow into the inlet or out of the outlet. Two toroidal transformer cores 35, 36 each extend around an arm of the closed loop of tube 30. The core 35 has an input winding 37 which is coupled to a source of alternating current supply indicated diagrammatically at 38. Also wound on the core 35 is a winding 39 which is connected in series with an adjustable conductance 40 and a winding 41 on the core 36. An output winding 42 on this core is coupled to a detector 43. It will be seen that the circuit arrangement of Figure 2 is identical with that of Figure 1. The coupled windings 39, 41 induce a flux in the core 36 from the core 35 and this flux can be balanced by the flux due to the coupling of the cores 35 and 36 through the loop of the liquid. The balancing is effected by the adjustment of the adjustable conductance 40 and the position of balance can be detected by the detector 43. It will be appreciated that the arrangement of Figure 2 measures the conductances in parallel of the liquid and of the tube 30. By making a first measurement using only the tube without any liquid in it, the conductance of the tubing can be measured and, hence a correction can be made to a measurement of the combined conductance of the tube and liquid to correct for the conductance of the tubing. However, by making the tube of material have a high resistance compared with that of the liquid, this correction can be made quite small. It will also be noted that this correction will correct not only for the conductance of the tubing but also for any cross-talk between the cores 35, 36.

It will be seen that, in the embodiment described above, the conductance of a liquid can

be measured without having any electrodes in the liquid by using a bridge method in which a null indication is obtained and the required conductance is obtained by a reading on an adjustable standard.

WHAT WE CLAIM IS:—

1. Apparatus for measuring the conductance of a liquid comprising an input transformer with a core carrying an alternating current input winding and a secondary winding which latter forms a first ratio arm, said secondary winding being adjustably coupled by a standard conductance to an input winding on a second core having an output winding coupled to a null-balance detector in which a loop of liquid in an annular vessel is coupled around the core of said input transformer and around said second core, the loop being arranged to form thereby a second ratio arm as well as the conductance to be measured whereby the coupling between the cores via the liquid loop may be balanced against the coupling via the standard conductance by adjustment of the latter coupling to give a null indication on the detector so that the adjustment of the coupling via the standard impedance is a measure of the conductance of the liquid loop.

2. Apparatus as claimed in claim 1 wherein said standard conductance is connected directly to said secondary winding.

3. Apparatus as claimed in either claim 1 or claim 2, wherein said standard conductance is an adjustable standard.

4. Apparatus as claimed in claim 2 wherein said standard conductance is a fixed standard and is connected to an adjustable tap on said secondary winding.

5. Apparatus as claimed in claim 1 wherein said standard conductance is connected to a tap on a potentiometer connected across said secondary winding.

6. Apparatus as claimed in claim 5 wherein said potentiometer is an alternating current decade potentiometer.

7. Apparatus as claimed in any of the preceding claims wherein the liquid loop is contained in an annular vessel of relatively non-conductive tubing.

8. Apparatus as claimed in claim 7 wherein the tubing is formed as a closed loop arranged in an upright plane with an inlet at the top.

9. Apparatus as claimed in any of the preceding claims wherein the detector winding is a primary winding of an output current transformer having a secondary winding wiich is connected to the detector.

10. Apparatus for measuring the conductance of a liquid substantially as described with reference to the accompanying drawings.

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PROVISIONAL SPECIFICATION

Improvements in or relating to the Measurement of the Electrical Conductance of Liquids

We, THE WAYNE KERR LABORATORIES LIMITED, a British Company, and RAYMOND CALVERT, a British Subject, both of the Company's address, 3, Sycamore Grove, New Malden, Surrey, do hereby declare this invention to be described in the following statement:—

This invention relates to the measurement of the electrical conductance of liquids.

The normal methods for measuring the conductance of a liquid require that electrodes should be arranged in contact with the liquid in order to make electrical connection between the liquid and the measuring circuit. Difficulties arise in the use of electrodes from chemical action of the liquid on the electrodes and/or from generation of gases which are adsorbed on the surface of the electrodes. There are thus considerable difficulties in measuring for example, the conductance of a very corrosive liquid.

It has been proposed to measure the conductance of a liquid by arranging an insulating tube containing the liquid in the form of a closed loop linked with two transformer cores, one of which carries a primary winding energised with alternating current and the other of which carries a secondary winding connected to a current measuring instrument. It is an object of the present invention to provide an improved apparatus for measuring the conductance of a liquid making use of closed loop of liquid linking two transformer cores.

According to this invention, apparatus for measuring the conductance of a liquid comprises an inductive ratio-arm alternating current bridge in which a loop of liquid in an annular vessel is coupled around a core of an inductance forming one of the ratio arms and around a core of a detector winding, the loop being arranged to form thereby the second of the ratio windings as well as the conductance to be measured. With this apparatus there are no electric connections between the liquid and the measuring circuit but the loop, or loops, of liquid forms the necessary coupling into the measuring circuit.

It is convenient to use a transformer ratio arm bridge for the measurement of the conductance and thus, in one arrangement, the apparatus comprises an alternating-current transformer ratio arm bridge with an input voltage-transformer which has an alternating voltage winding and a secondary winding on a core, the secondary winding forming one of the ratio arms of the bridge, a detector winding having a core and connected, in series with a

standard conductance, across the whole or part of said secondary winding, and a loop or loops of the liquid coupled around both the cores, which loop or loops thereby forms the second ratio arm as well as the conductance to be measured. The standard conductance may be connected directly to the aforementioned secondary winding and either may be a variable standard or may be a fixed standard connected to an adjustable tap on the winding. Alternatively the standard conductance might be connected to a tap on a potentiometer, for example an alternating current decade potentiometer, connected across the secondary winding.

The annular vessel embracing both cores is preferably constructed of non-conductive tubing such as, for example, glass or polythene. In a simple form, the tubing might be a closed loop which is used in an upright plane with an inlet arranged at the top. The tubing would be filled completely with the liquid under measurement and the inlet closed, for example, by a stopper.

The form of bridge described above measures conductances in parallel and hence would measure the parallel conductance of the tubing and of the liquid. Thus, by making a first measurement using only the tubing without the liquid, the conductance of the tubing can be measured and hence a correction can be made to a measurement of the combined conduction of the tubing and liquid to correct for the conductance of the tubing. It will be appreciated however that errors will be minimised if the conductance of the tubing is made as small as possible. It will also be noted that the correction obtained by making a first measurement using only the tubing without the liquid will correct not only for the conductance of the tubing but also any cross-talk between the input and output circuits of the bridge.

In the simplest case the tubing makes only a single turn around each of the cores and generally this will be the most convenient form. The number of turns on the two cores determines the bridge ratio and if this is known and if the cross-sectional area and length of the tubing is measured, it is possible, by the bridge, to determine the absolute value of the conductance of the liquid under test. If the cross sectional area of the tubing is not known with sufficient accuracy, the bridge could be calibrated by making a preliminary measurement with the tubing filled with a liquid of known conductivity.

Conveniently the detector winding is a primary winding of an output current transformer having a secondary winding which is connected to the detector.

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111 & 112, Hatton Garden, London, E.C.1,
Chartered Patent Agents.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1960.
Published by The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

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COMPLETE SPECIFICATION
This drawing is a reproduction of the Original on a reduced scale.

Fig.1.

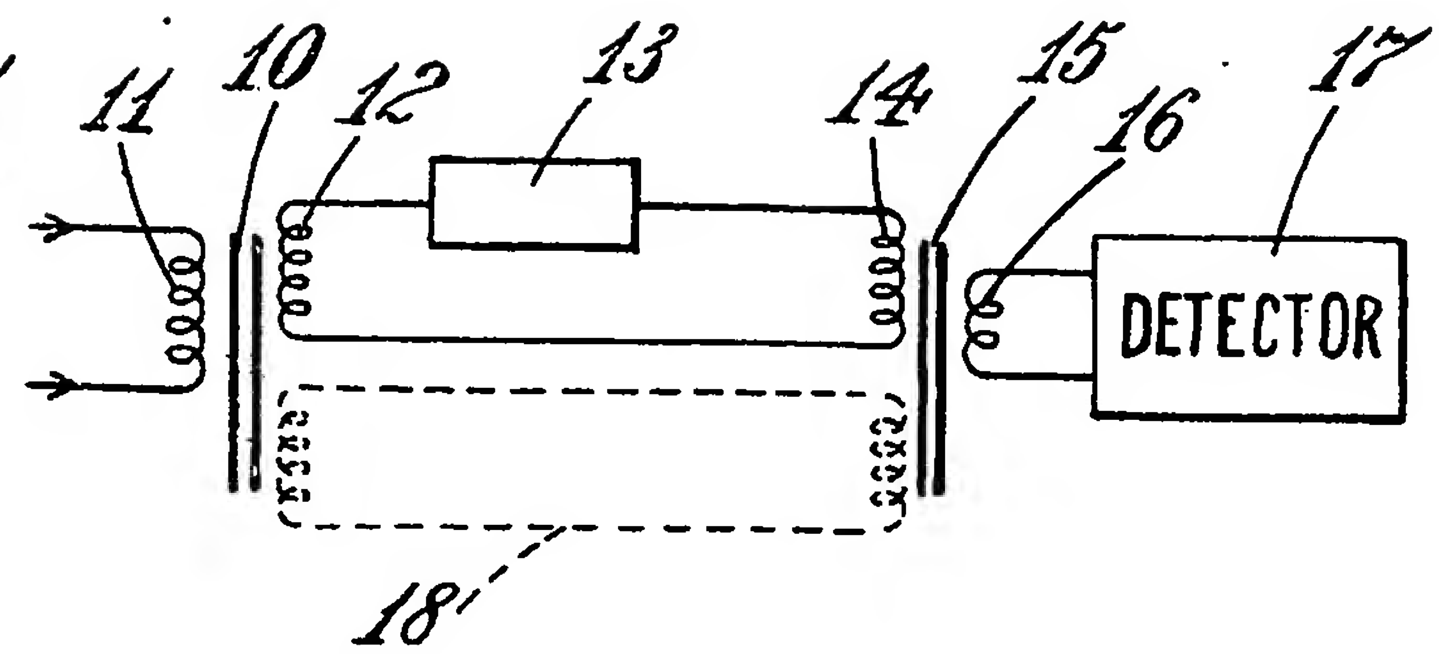

Fig.2.